Appendix F
Emergency Flood Protection

F-1. Introduction

a. Flood fighting. Flood fighting can be defined as those emergency operations that are taken in advance of and during a flood to prevent or minimize damages to public and private property. As defined herein, flood fighting includes the hasty construction of emergency levees; the overbuilding of existing levees or natural river banks; ring and U-shaped levees constructed around facilities or areas of high property value; preservation of vital facilities including water treatment plants and wells; power and communication facilities; protection of sanitary and storm sewer systems; and provisions for interior drainage treatment during flood stages. Flood fighting plans should acknowledge that it may not be feasible to protect entire communities based on economic or time and equipment considerations; therefore, evacuation of certain areas may be a necessary facet of an emergency operation.

b. Recommended local organization. Each community with a flood history should establish an organization and written plans for the purpose of conducting flood fighting operations. These plans should include identification of flood-prone areas and previous high water marks; flood fighting or evacuation plans; delegation of responsibilities; lists of important suppliers of materials and special equipment; lists of local contractors; and establishment of earth borrow sites, etc. The plan should further provide for the establishment of an emergency operation center and list various assistance programs available, either through the State or Federal government. Further assistance in developing these plans can be provided by the State or local Civil Defense Director in the area.

F-2. Flood Barrier Construction

a. Introduction. The two basic features of an emergency levee system include the flood barrier, generally constructed of earth fill, and the related interior drainage treatment. It is desirable that individuals assigned to a flood-fight situation have prior knowledge of flood barrier construction, interior drainage, and related flood-fight problems which they may encounter. They should also be acquainted with the past flood emergency efforts, historical flood stages, and forecasted stages for the community. The following information will provide personnel with guidelines based on actual experience. However, it cannot be over emphasized that individual resourcefulness is a key element in a successful flood fight.

b. Preliminary work.

(1) Alignment. A complete alignment for the barrier should be established promptly and, if possible, in cooperation with State or local floodplain management officials. The alignment should be the shortest practical route, provide the maximum practical protection, and take advantage of any high ground where practicable. The flood barrier should be kept as far landward of the river as possible to prevent encroachment on the floodway and to provide maximum space for overbank flows. This is especially important for smaller floodways where encroachment would directly impact the water surface profile. Sharp bends should be avoided. Topographic, plat, or city street maps may be useful in selecting alignment. In choosing the alignment, consideration should be given as to whether sufficient time remains to complete construction before the flood crest arrival. Potentially unstable river banks should be avoided. Keep as many trees and brush between the levee and river as possible to help deflect current, ice, and debris. However, in constricted areas of the river, 1.52 m (5 ft), and preferably 3.05 m (10 ft), should be allowed between the levee toe and vertical obstructions such as trees. In urban areas, many communities within a flood prone

area already have some levees in-place. These communities typically fight the flood along this primary line of defense. Moving the alignment farther landward creates problems in determining methods to stop floodwater backup through storm and sanitary sewer lines. It could also leave storm and sanitary lift stations on the riverside of the flood barrier. Leaving some homes outside the line of protection also exposes the watermains to floodwater infiltration. Right-of-way considerations may also influence the final alignment. Generally, the city or county engineer will assist in laying out the line and grade for the barrier, or a professional surveyor may be available. However, if help is not available, a hand-level along with a known elevation can be used to lay out rough grade. As soon as the alignment is firm, quantities of earthwork should be estimated for establishing equipment and borrow requirements.

(2) Drainage. In laying out a flood barrier, the problem of interior drainage from snowmelt, rain, or sewer backup should be considered. A certain amount of ponding, if valuable property will not be damaged, is not detrimental and may be allowed. The excess interior water can be pumped out over the levee if pumps are available.

(3) Borrow area and haul road. The two prime requisites for a borrow area are that adequate material be available and that the site be accessible at all times. The quantity estimate plus an additional 50 percent should provide the basis for the area requirement. The area must be located so that it will not become isolated from the project by high water. The borrow area should also be located where the present water table, if known, and the water table levels caused by high water will not hinder or stop its use. If possible, a borrow area should be selected which will provide suitable materials for levee construction as covered below. Local contractors and local officials are the best source of information on available borrow areas. If undeveloped, the area should be cleared of brush, trees, and debris, with topsoil and surface humus being stripped. In cold regions in early spring, it will probably be necessary to rip the area to remove frozen material. An effort should be made to borrow from the area in such a manner that the area will be relatively smooth and free-draining when the operation is complete. The haul road may be an existing road or street, or it may have to be constructed. To mitigate damages it is highly desirable to use unpaved trails and roads, or to construct a road if the haul distance is short. In any case, the road should be maintained to avoid unnecessary traffic delays. The use of flagmen and warning signs is mandatory at major crossings such as highways, near schools, and at major pedestrian crossings. A borrow area, or source of sand for sandbags, should also be located promptly. This can become a critical item of supply in some areas due to long haul, project isolation, etc. It may become necessary to stockpile material near anticipated trouble areas.

(4) Equipment. One of the important considerations in earthwork construction is the selection of proper equipment to do the work. Under emergency conditions, obtaining normally specified earthwork equipment will be difficult and the work will generally be done with locally available equipment. It may be wise to call for technical assistance in the early contract stage to insure that proper and efficient equipment use is proposed. If possible, compaction equipment should be used in flood-barrier construction. This may involve sheepsfoot, rubber-tired, or vibratory rollers. Scrapers should be used for hauling when possible because of speed (on short haul) and large capacity. Truck haul, however, has been the most widely used. A ripper will be necessary for opening borrow areas in the early spring if the ground is frozen. A bulldozer of some size is mandatory on the job to help spread dumped fill and provide minimum compaction.

(5) Construction contract. The initiation of a construction contract under emergency conditions is very unique in that sole judgment as to the competence and capabilities of the contractor lies with field personnel. Field personnel, therefore, must be somewhat knowledgeable in construction operations. The initial contract is very important in that it delineates what equipment must be accounted for on the project and what is available for construction. During construction, if it becomes obvious that the equipment provided by the initial contract is inadequate to provide reasonably good construction or timely completion, a new or supplemental contract may be required. Procedures are the same as in the initial contract. Flexibility may be

built into the original contract if it can be foreseen that additional pieces of equipment will ultimately be used.

(6) Supplies. Early anticipation of floodfight problems will aid greatly in providing necessary and sufficient supplies on hand. These include sandbags, polyethylene, pumps, etc. The importance of initiative, resourcefulness, and foresight of the individual on the project cannot be over emphasized. Technical assistance may be invaluable in locating potential problem areas which, with proper materials at hand, could be alleviated early.

c. Earth fill levees.

(1) Foundation preparation. Prior to embankment construction, the foundation area along the levee alignment should be prepared. This is particularly important if the levee is to be left in place. Since spring flooding is the only condition providing much advance warning, the first item of work in cold regions probably will be snow removal. The snow should be pushed riverward so as to decrease ponding when the snow melts. Trees should be cut and the stumps removed. All obstructions above the ground surface should be removed, if possible. This will include brush, structures, snags, and similar debris. The foundation should then be stripped of topsoils and surface humus. (Clearing and grubbing, structure removal, and stripping should be performed only if time permits.) Stripping may be impossible if the ground is frozen. In this case, the foundation should be ripped or scarified, if possible, to provide a rough surface for bond with the embankment. Every effort should be made to remove all ice or soil containing many ice lenses. Frost or frozen ground can give a false sense of security in the early stages of a flood fight. It can act as a rigid boundary and support the levee; but on thawing, soil strength may be reduced sufficiently for cracks or slides to develop. It also forms an impervious barrier to prevent seepage. This may result in a considerable buildup in pressure under the soils landward of the levee, and upon thawing pressure may be sufficient to cause sudden blowouts. If this condition exists it must be monitored, and one must be prepared to act quickly if sliding or sand boils develop. If stripping is possible, the material should be pushed landward and riverward of the toe of levee and windrowed. After the flood, this material may be spread on the slopes to provide topsoil for vegetation.

(2) Materials. Earth fill materials for emergency levees will usually come from local borrow areas. An attempt should be made to utilize materials which are compatible with the foundation materials. Due to time limitations, however, any local materials may be used if reasonable construction procedures are followed. The material should be relatively clean (free of debris) and should not contain large frozen pieces of earth.

(a) Clay. Clay is preferred because the section can be made smaller (steeper side slopes). Clay is also relatively impervious (will not readily permit passing of water) and has relatively high resistance to erosion in a compacted state. A disadvantage in using clay is that adequate compaction is difficult to obtain without proper equipment and when the material is wet. Another disadvantage is if the clay is wet and sub-freezing temperatures occur, this may cause the material to freeze in the borrow pit and hauling equipment. Weather could cause delays and should definitely be considered in the overall construction effort.

(b) Sand. If sand is used, the section should comply as closely as possible with recommendations in paragraph F-2.C.(3)(b) below. Steep slopes without poly coverage on the riverside slope will result in seepage through the levee that exits on the landward slope causing slumping of the slope and potential overall failure if it occurs over an extended period of time.

(c) Silt. Material which is primarily silt should be avoided. If used, poly facing must be applied to the river slope. In addition to being very erodible, silt, upon wetting, tends to collapse if not properly compacted.

(3) Levee section.

(a) General. In standard levee design the configuration of the levee is generally dictated by the foundation soils and the materials available for construction. Therefore, even under emergency conditions, an attempt should be made to make the embankment compatible with the foundation. Information on foundation soils may be available from local officials or engineers, and it should be utilized. The two levee sections cited below are classical and idealized, and usual field conditions depart from them to various degrees. However, if they are used as a guide, possible serious flood-fight problems could be lessened during high water. In determining the top width of any type of section, consideration should be given as to whether a revised forecast will require additional fill to be placed. A top width adequate for construction equipment will facilitate raising the levee. Finally, actual dike construction will, in most cases, depend on time, materials, and right-of-way available.

(b) Sand section. Use 1 V (Vertical) on 3 H (Horizontal) toward a river, 1 V on 5 H landward slope, and 3.05-m (10-ft) top width.

(c) Clay section. Generally 1 V on 2 1/2 H slopes are used but for low height levees 1 V on 2 H slopes have been used successfully. It is important to always use a 3.05 m (10 ft) top width. When clay levees are constructed on pervious foundations, the bottom width may not be adequate to reduce the potential for foundation piping. This can be accomplished by using berms either landward or riverward of the levee. Berm thickness will be site specific. Berms reduce the potential for foundation piping, but do not reduce foundation seepage.

(4) Placement and compaction. As stated above, obtaining proper compaction equipment for a given soil type will be difficult. It is expected in most cases that the only compaction will be from that due to the hauling and spreading equipment; i.e., construction traffic routed over the fill. Levee height should provide 0.61 m (2 ft) of freeboard above forecast flood crest. In urban areas, the upstream end of the project should use a larger freeboard than the downstream end.

(5) Slope protection.

(a) General. Methods of protecting levee slopes from current scour, wave wash, seepage, and debris damage are numerous and varied. However, during a flood emergency, time, availability of materials, cost and construction capability preclude the use of all accepted methods of permanent slope protection. Field personnel must decide the type and extent of slope protection the emergency levee will need. Several methods of protection have been established which prove highly effective in an emergency. Again, resourcefulness on the part of the field personnel may be necessary for success.

(b) Polyethylene and sandbags. Experience has shown that a combination of polyethylene (poly) and sandbags is one of the most expedient, effective, and economical methods of combating slope attack in a flood situation. Poly and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. Ideally, poly and sandbag protection should be placed in the dry. However, many cases of unexpected slope attack will occur during high water, and a method for placement in the wet is covered below. See Figures F-1 to F-4 for suggested methods of laying poly and sandbags. Since each flood fight project is generally unique (river, personnel available, materials, etc.), specific details of placement and materials handling will not be covered. Personnel must be aware of resources available when using poly and sandbags.

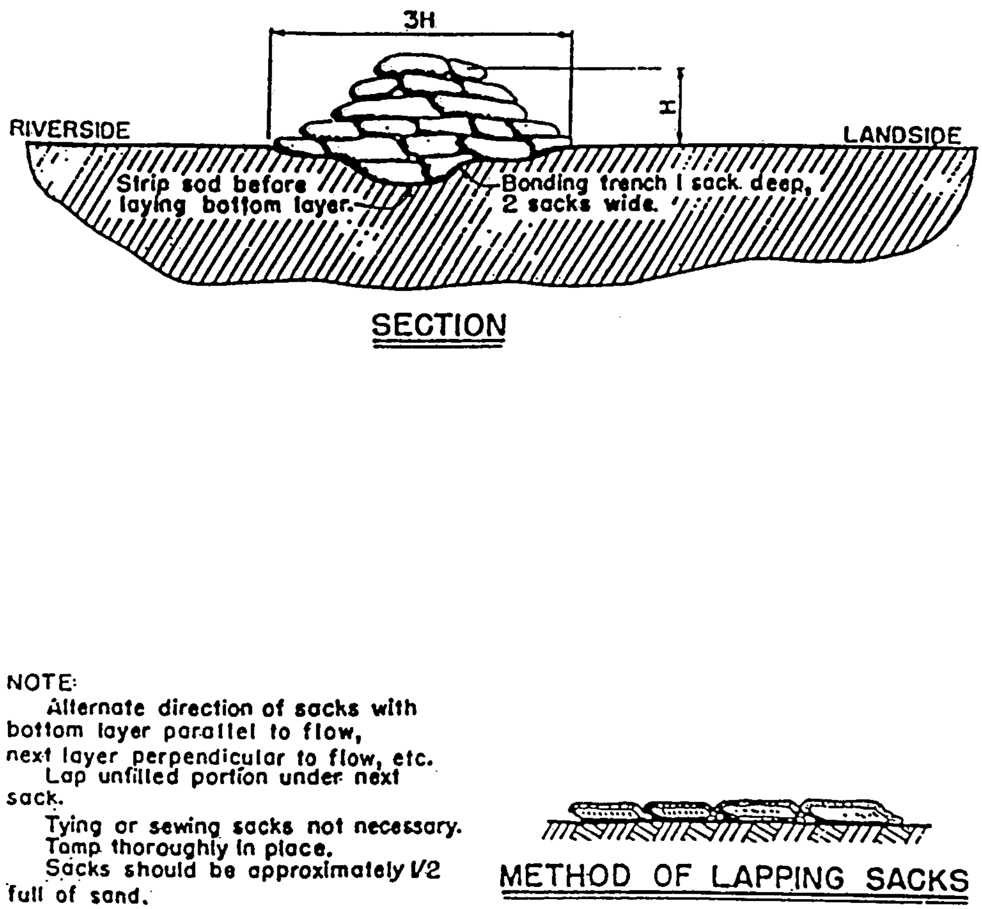

Figure F-1. Sandbag barrier

(c) Toe anchorage and poly placement. Anchoring the poly along the riverward toe is important for a successful job. It may be done in three different ways: (1) After completion of the levee, a trench excavated along the toe, poly placed in the trench, and the trench backfilled; (2) Poly placed flat-out away from the toe, and earth pushed over the flap; and (3) Poly placed flat-out from the toe and one or more rows of sandbags placed over the flap. The poly should then be unrolled up the slope and over the top enough to allow for anchoring with sandbags. Poly should be placed from downstream to upstream along the slopes and overlapped at least 0.61 m (2 ft). The poly is now ready for the “hold-down” sandbags.

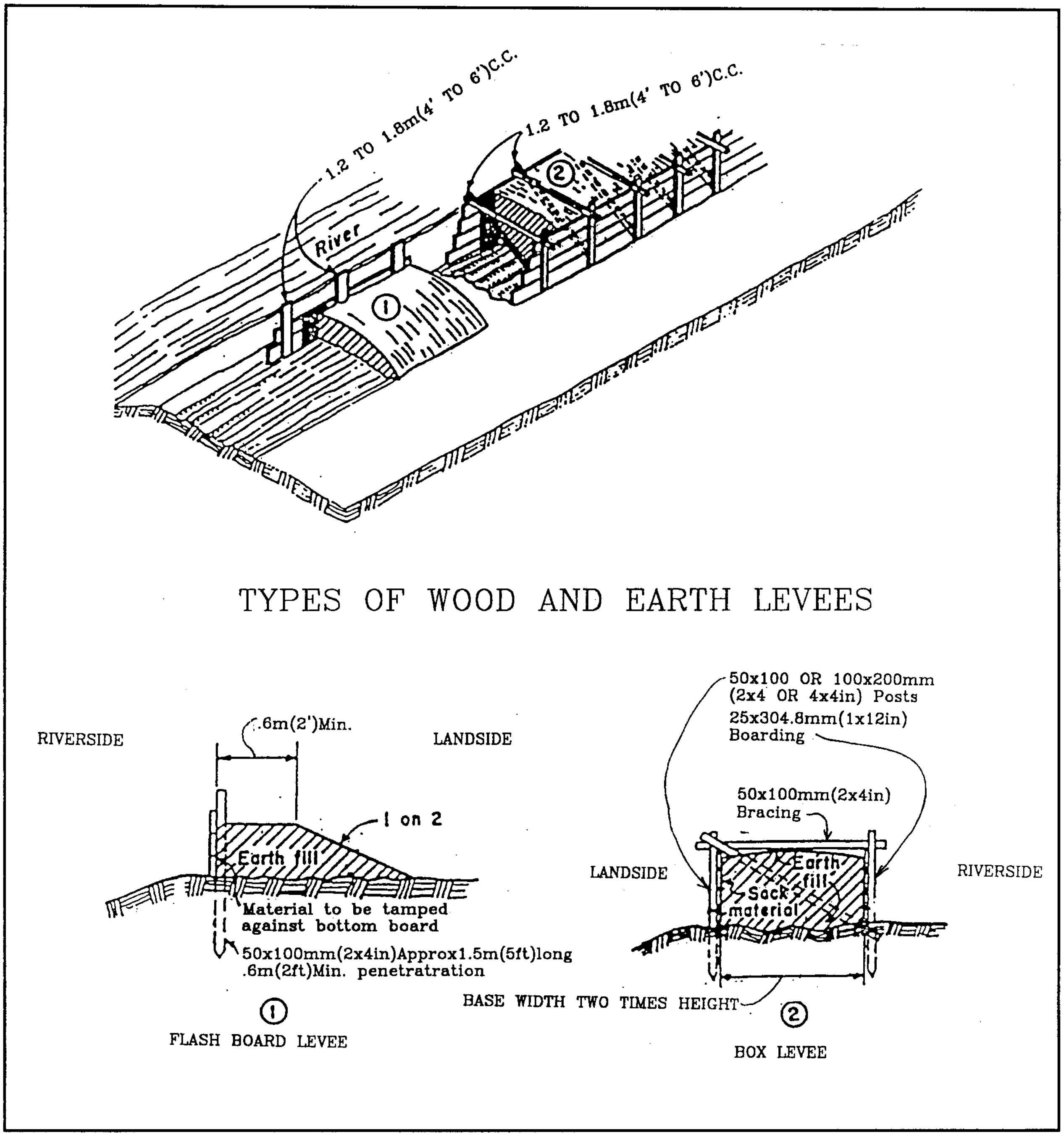

Figure F-2. Flash board and box levee

(d) Slope anchorage. It is mandatory that poly placed on levee slopes be held down. An effective method of anchoring poly is a grid system of sandbags, unless extremely high velocities, heavy debris, or a large amount of ice is anticipated. Then a solid blanket of bags over the poly should be used. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Various grid systems include vertical rows of lapped bags, two-by-four lumber held down by attached bags, and rows

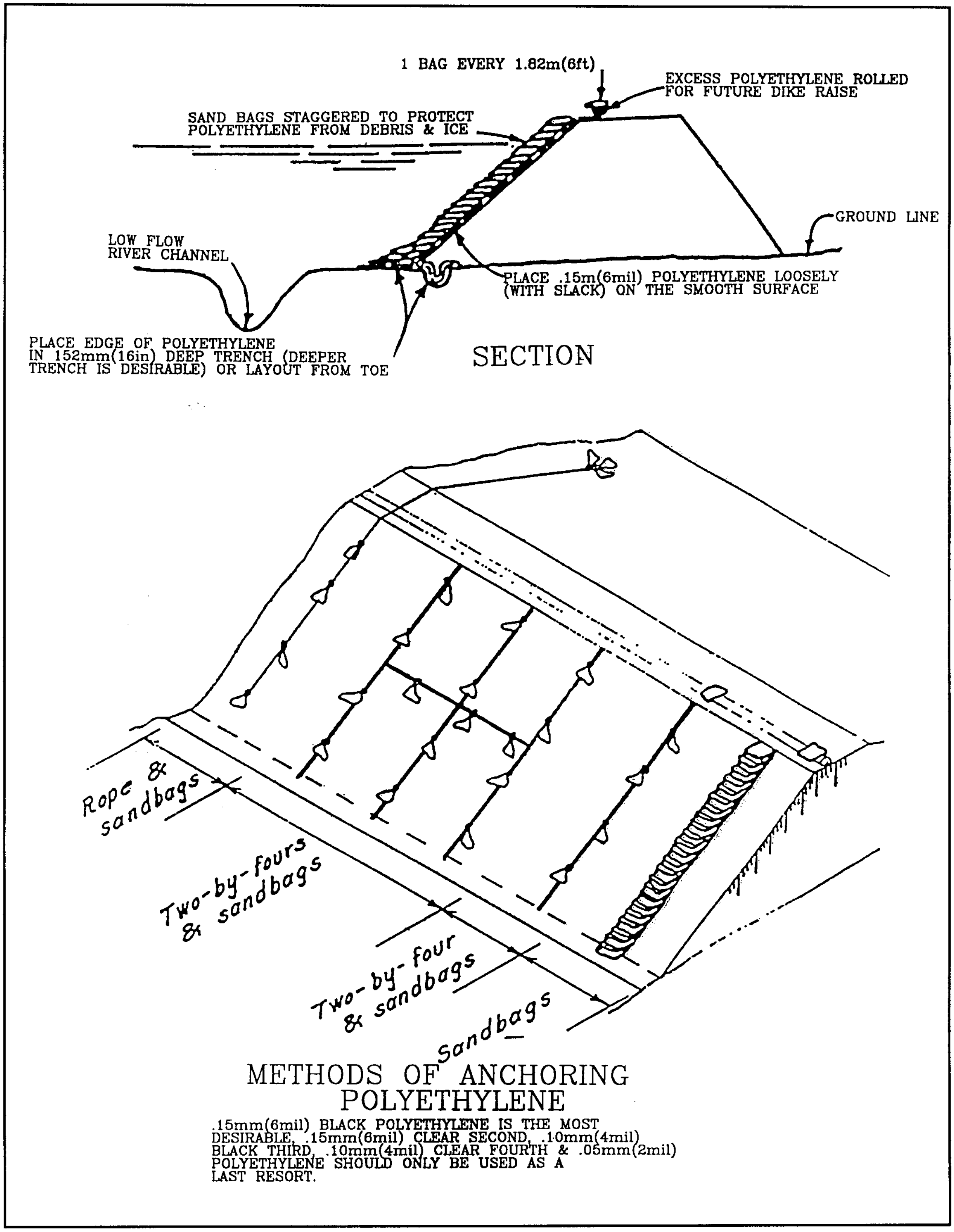

Figure F-3. Placement of polyethylene sheeting on temporary levee

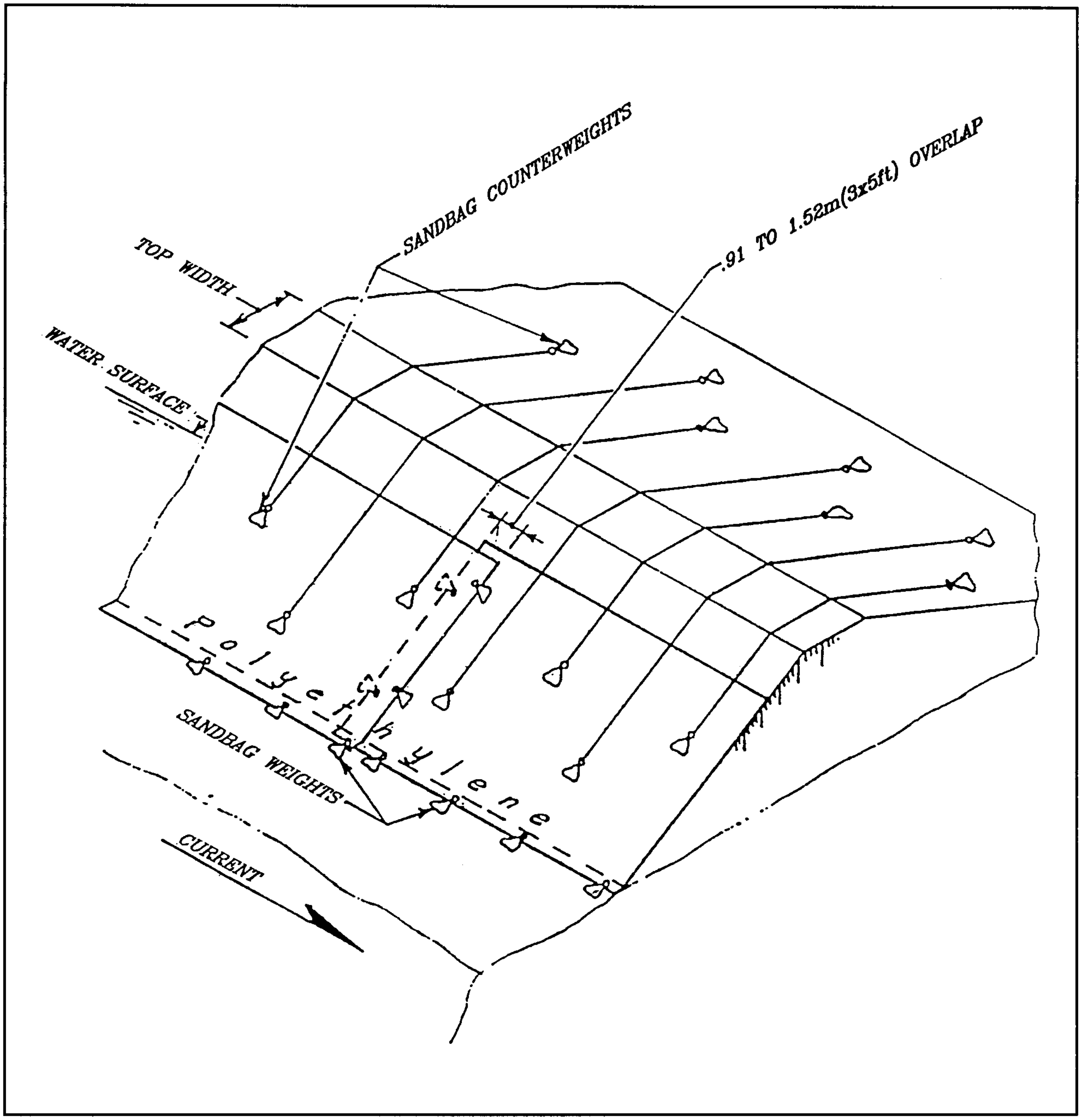

Figure F-4. Placement of polyethylene sheeting in the wet

of bags held by a continuous rope tied to each bag. Poly can also be held down by a system using two bags tied with rope and the rope saddled over the levee crown with a bag on each slope.

(e) Placement in the wet. In many situations during high water, poly and sandbags placed in the wet must provide the emergency protection. Wet placement may also be required to replace or maintain damaged poly or poly displaced by current action. Figure F-4 shows a typical section of levee covered in the wet. Sandbag anchors are formed at the bottom edge and ends of the poly by bunching the poly around a fistful of hand or rock and tying the sandbags to this fist-sized ball. Counterweights consisting of two or more sandbags connected by a length of 6.35-mm (1/4-in.) rope are used to hold the center portion of the poly down. The number of counterweights will depend on the uniformity of the levee slope and current velocity. Placement of the poly consists of first casting out the poly sheet with the bottom weights and then adding counterweights to slowly sink the poly sheet into place. The poly, in most cases, will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added to insure that no air voids exist between the poly and the levee face and to keep the poly from flapping or being carried away in the current. For this reason, it is important to have enough counterweights prepared prior to the placement of the sheet.

(f) Overuse of poly. In past floods there has been a tendency to overuse and in some cases misuse poly on slopes. For example, on well compacted clay embankments, in areas of relatively low velocities, use of poly would be unnecessary. Also, placement of poly on landward slopes to prevent seepage must not be done. It will only force seepage to another exit and may prove detrimental. Poly has been used on the landside slope of levees to prevent rainwater from entering a crack where slope movement has occurred, particularly in fat clay soils. Keeping water out of the cracks resulting from slope movements is desirable to prevent lubrication and additional hydrostatic pressure on the slip surface.

(g) Riprap. Riprap is a positive means of providing slope protection and has been used in a few cases where erosive forces were too large to effectively control by other means. Objections to using riprap when flood fighting are: (1) rather costly; (2) large amount necessary to protect a given area; (3) availability; and (4) little control over its placement, particularly in the wet.

(h) Groins. In the past, small groins, extending 3.05 m (10 ft) or more into the channel were effective in deflecting current away from the levees. Groins can be constructed by using sandbags, snow fence, rock, compacted earth, or any other substantial materials that are available. Preferably groins should be placed in the dry and at locations where severe scour may be anticipated. Consideration of the hydraulic aspects of placing groins should be given, because haphazard placement may be detrimental. Hydraulic technical assistance should be sought if doubts arise in the use of groins. Construction of groins during high water will be very difficult and results will generally be minimal. If something other than compacted fill is used, some form of anchorage or bonding should be provided. (For example, snow fence anchored to a tree beyond the toe of the levee.)

(i) Log booms. Log booms have been used to protect levee slopes from debris or ice attack. Logs are cabled together and anchored with a dead man in the levee. The boom will float out in the current and, depending on log size, will deflect floating objects.

(j) Miscellaneous measures. Several other methods of slope protection have been used. Straw bales pegged into the slope may be successful against wave action, as is straw spread on the slope and overlain with snow fence.

(6) Sandbag dikes. The sandbag dike should not be considered as a primary-flood barrier. The main objections to their use are that the materials (bags and sand) are quite costly; they require a tremendous amount of manpower; and are time consuming to construct. They are also very difficult to raise if the flood forecasts are revised. Sandbag dikes should be used where a very low and relatively short barrier is required and earth fill would not be practicable, such as in the freeboard range along an arterial street. They are very useful in constricted areas such as around or very close to buildings, where rights-of-way would preclude using earth fill. They are also useful where temporary closure is required, such as roads and railroad tracks. A polyethylene seepage barrier should be incorporated into the sandbag structure. The poly must be on the riverward slope and brought up immediately behind the outermost layer of bags. The poly should be

keyed-in to a trench at the toe and anchored, or, at best, lapped under the sandbags for anchorage. See Figure F-1 for recommended practices in sandbag dike construction. A few points to be aware of in sandbag construction are: (1) sand, or predominantly sandy or gravelly material should be used; (2) extremely fine, clean sand, such as washed mortar sand, should be avoided; (3) bags should be 1/2 full; (4) bags should be lapped when placing; (5) bags should be tamped tightly in place; and (6) the base width should be wide enough to resist the head at high water. Sandbagging is also practical for raising a narrow levee, or when construction equipment cannot be used. Sandbag raises should be limited to 0.91 m (3 ft), if possible.

(7) Miscellaneous flood barriers. In addition to earth fill and sandbag levees, two other types of flood barriers should be mentioned. They are the flashboard and the box levees, both of which are constructed using lumber and earth fill (see Figure F-2). They may be used for capping a levee or as a barrier in highly constricted areas. Two disadvantages in using these barriers are the long construction time involved and very high cost. Therefore, these barriers are not recommended, unless a very unusual situation warrants their use.

F-3. Emergency Interior Drainage Treatment

a. General. High river stages often disrupt the normal drainage of sanitary and storm sewer systems, render sewage treatment plants inoperative, and cause backup in sewers and the discharge of untreated sewage directly into the river. When the river recedes, some of the sewage may be trapped in low lying pockets to remain as a possible source of contamination. Hastily constructed dikes intended to keep out river waters may also seal off normal outlet channels for local runoff, creating large ponds on the landward side of the dikes, making the levees vulnerable from both sides. If the ponding is excessive, it may nullify the protection afforded by the dikes even if they are not overtopped. Sewers may also back up because of this ponding.

b. Preliminary work. In order to arrive at a reasonable plan for interior drainage treatment, several items of information must be obtained by field personnel. These are:

(1) Size of drainage area.

(2) Pumping capacity and/or ponding required.

(3) Basic plan for treatment.

(4) Storm and sanitary sewer and water line maps, if available.

(5) Location of sewer outfalls (abandoned or in use).

(6) Inventory of available local pumping facilities.

(7) Probable location of pumping equipment.

(8) Whether additional ditching is necessary to drain surface runoff to ponding and/or pump locations.

(9) Location of septic tanks and drain fields (abandoned or in use).

c. Pumps, types, sizes, and capacities.

(1) Storm sewer pumps. Table F-1 indicates the size of pump needed to handle the full flow discharge from sewer pipes up to 610 mm (24 in.) in diameter. Table F-2 shows sizes and capacities of agricultural--type pumps which may be useful in ponding areas.

Table F-1
Matching Pipe Size to Pump Size

Sewer Pipe Size, mm (in.)	Probable Required Pump Size, mm (in.)
152.4 (6)	50.8 (2)
203.2 (8)	50.8 to 76.2 (2 to 3)
254.0 (10)	76.2 to 101.6 (3 to 4)
304.8 (12)	101.6 to 152.4 (4 to 6)
381.0 (15)	152.4 to 203.2 (6 to 8)
457.2 (18)	152.4 to 254 (6 to 10)
533.4 (21)	203.2 to 254 (8 to 10)
609.6 (24)	254 to 304.8 (10 to 12)

(2) Fire engine pumps. The ordinary fire pumper has a 101.6 mm (4-in.) suction connection and a pumping capacity of about 2838.75 ℓ/min (750 gpm). Use only if absolutely necessary.

(3) Pump discharge piping. The Crisafulli pumps are generally supplied with 15.24-m (50-ft) lengths of butyl rubber hose. Care must be taken to prevent damage to the hose. Irrigation pipe or small diameter culverts will also serve as discharge piping. Care should be taken to extend pump discharge lines riverward far enough to not cause erosion of the levee. On 304.8 mm (12-in.) or larger lines, substantial anchorage is required. These pumps must not be operated on slopes greater than 20 degrees from horizontal.

(4) Sanitary sewage pumping. During high water, increased infiltration into sanitary sewers may necessitate increased pumping at the sewage treatment plant or at manholes at various locations to keep the system functioning. To estimate the quantity of sewage, allow 0.378 m^3 (100 gal) per capita per day for sanitary sewage and an infiltration allowance of 35.28 m^3 per km-day (15,000 g/mile-day) of sewer per day. In some cases, it will be necessary to pump the entire amount of sewage, and in other cases only the added infiltration will have to be pumped to keep a system in operation.

Example: Estimate pumping capacity required at an emergency pumping station to be set up at the first manhole above the sewage treatment plant for a city of 5,000 population and approximately 48.24 km (30 miles) of sewer (estimated from map of city). In this case, it is assumed that the treatment plant will not operate at all.

Required capacity = (infiltration) + (sewage)

Sewage demand: $$\frac{5000\ \text{per} \times 0.378\ \text{m}^3/\text{person/day}}{24\ \text{hr} \times 60\ \text{min}} = 1.314\ m^3/\text{min}$$

$$\frac{5000\ \text{persons} \times 100\ \text{gal/person/day}}{24\ \text{hr} \times 60\ \text{min/hr}} = 347\ gpm$$

Table F-2
Crisafulli Pumps - Model CP 2 in. to 24 in.

Size mm (in.)	m^3/min (gal/min)	Head[a] m (ft)	Elec. kW (hp)	Gas or Diesel kW (hp)
50.8 (2)	0.56 (150)		0.745 (1)	
101.6 (4)	1.88 (500)		5.59 (7.5)	11.18(15)
152.4 (6)	3.76 (1000)		7.45 (10)	14.9 (20)
203.2 (8)	11.27 (3000)	3.04 (10)	11.18 (15)	18.62(25)
304.8 (12)	18.79 (5000)		18.62 (25)	29.8 (40)
406.4 (16)	35.70 (9500)		29.8 (40)	48.4 (65)
609.6 (24)	93.95 (25000)		55.88 (75)	104.3(140)
50.8 (2)	0.49 (130)		0.745 (1)	
101.6 (4)	1.84 (490)		7.45 (10)	14.9 (20)
152.4 (6)	3.19 (850)		11.18 (15)	18.62(25)
203.2 (8)	9.21 (2450)	6.1 (20)	14.9 (20)	26.08(35)
304.8 (12)	14.09 (3750)		22.35 (30)	37.2 (50)
406.4 (16)	30.06 (8000)		33.52 (45)	63.3 (85)
609.6 (24)	71.4 (19000)		74.5 (100)	141.6(190)
50.8 (2)	0.45 (120)		0.745 (1)	
101.6 (4)	1.79 (475)		8.94 (12)	18.62(25)
152.4 (6)	2.99 (795)		14.9 (20)	26.08(35)
203.2 (8)	8.08 (2150)	9.84 (30)	18.62 (25)	33.52(45)
304.8 (12)	12.96 (3450)		26.08 (35)	52.15(70)
406.4 (16)	26.68 (7100)		44.70 (60)	93.12(125)
609.6 (24)	62.38 (16600)		93.12 (125)	186.24(250)

[a] Use high head pumps for heads over 6.1 m or 59.71 KPa (20 ft).

$$\text{Infiltration: } \frac{35.31\ \text{m}^3}{\text{km}} \times 48.24\ \text{km}\ \frac{1}{24\ \text{hr} \times 60\ \text{min}} = 1.18\ \text{m}^3/\text{min}$$

$$\frac{15000\ \text{gal/mile/day} \times 30\ \text{miles}}{24\ \text{hr} \times 60\ \text{min/hr}} = 312\ gpm$$

Required pumping capacity: 2.49 m^3/min (659 gpm). From Table F-3, use one 101.6 mm (4-in.) pump or its equivalent.

Table F-3
Marlow Self Priming Centrifugal Pumps

Size mm (in.)	AGC Rating[a]	Capacity[b] m^3/min (gal/min)	Horsepower kW (hp)
38.1 (1.5)	4M	0.25 (67)	1.34 (1.8)
50.8 (2)	7-10M	0.44-0.63 (117-167)	1.71-3.66(2.3-4.9)
76.2 (3)	20-30M	1.26-1.89 (334-500)	3.66-8.36 (4.9-11.2)
101.6 (4)	30-40M	1.89-2.51 (500-665)	14.92-28.94 (20-38.8)
152.4 (6)	90M	5.67 (1500)	32.46 (43.5)
203.2 (8)	125M	7.87 (2080)	46.25 (62)
254.0 (10)		12.6 (3330)	46.25 (62)

[a] Gallons per hour, thousands.
[b] At 75 kPa (7.67-m, 25-ft) head.

d. Metal culverts.

(1) Pumping of ponded water is usually preferable to draining the water through a culvert since the tailwater (drainage end of culvert) could increase in elevation to a point higher than the inlet, and water could back up into the area being protected. Installation of a flapgate at the outlet end may be desirable to minimize backup.

(2) Table F-4 shows the capacity of corrugated pipe culverts on a flat slope, with H factor (head) representing the difference between the headwater level and tailwater level, assuming the outlet is submerged. If the outlet is not submerged the head equals the difference in elevation between the headwater level and 0.6 of the diameter of the pipe measured from the bottom of the pipe upward. The capacity would change for smooth pipe, pipe laid on a slope, or if headwalls or wingwalls are used.

(3) If a culvert is desired to pass water from a creek through a levee, a computation of the drainage basin by an engineer is required to determine pipe size.

e. Preventing backflow in sewer lines.

(1) Watertight sluice gates or flap gates are one answer. Emergency stoppers may be constructed of lumber, sandbags, or other materials, using poly as a seal, preferably placed on the discharge end of the outfall pipe.

(2) Figures F-5 and F-6 contain manufacturer's literature on prefabricated rubber pipe stoppers which can be placed in the outlet opening of a manhole.

(3) Figures F-7 to F-11 illustrate methods of sealing off the outlet openings of a manhole with standard materials which are normally available so that the manhole may be used as an emergency pumping station.

F-4. Flood Fight Problems

a. General. Problem situations which arise during a flood fight are varied and innumerable. The problems covered below and in “Emergency Interior Drainage Treatment” are those which are considered most critical to the integrity of the flood barrier system. It would be impossible to enumerate all of the problems, such as supplies, personnel, communication, etc., which field personnel must handle. The most valuable asset of field personnel under emergency conditions is their common sense. Many problems can be solved instantly and with less effort through the application of good common sense and human relations. Problems, such as those below, can be identified early only if a well organized levee patrol system with a good communication system exists. The problems are presented with the assumption that high water is on the levee slopes.

b. Overtopping. Overtopping of a levee is the flowing of water over the levee crown. Since most emergency levees are of an urban nature, overtopping should be prevented at any cost. Overtopping will generally be caused by: (1) unusual hydrologic phenomena, including unexpected rainfall, faster than expected rainfall, faster than expected snowmelt, and ice and debris blockages, which cause a much higher stage than anticipated; (2) insufficient time in which to complete the flood barrier; or (3) unexpected settlement of the barrier. Generally, the flood barriers are constructed 0.61 m (2 ft) above the crest prediction. If the crest prediction is raised during construction, additional height must be added to the barrier. Capping should be done with earth fill or sandbags, using normal construction procedures. For levee construction, the 3.05 m (10 ft) top width allows the barrier to be raised relatively quickly with regular

Table F-4a
Capacity of Corrugated Metal Pipe Culverts
Without Headwalls and With Outlet Submerged (outlet control-full flow) (Circular) (metric Units)

Dia. In mm		CUBIC METERS PER SECOND																
		Pipe Pressure in kPa																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.050	0.056	0.071	0.085	0.1	0.113
304.2	Length = 61 m	2.98	4.17	5.07	5.96	6.6	7.15	8.34	9.23	10.1	11	11.9	12.5	13.1	14.9	16.1	17.3	18.5
381		5.07	7.15	8.64	10.13	11.3	12.2	14.3	15.8	17.3	18.8	20.3	21.2	22.4	25	27.4	29.5	32.8
457.2		7.75	10.73	13.11	15.5	17	18.5	21.5	23.8	26.2	28.3	29.8	32.8	32.8	38.7	41.7	44.7	47.7
533.4		10.7	15.2	18.5	21.4	23.8	26.2	29.8	32.8	35.8	38.7	41.7	44.7	47.7	53.6	56.6	62.6	65.6
609.6		14.6	20.3	25	28.6	32.8	35.8	41.7	44.7	50.7	53.6	56.6	59.6	62.6	71.5	77.5	83.4	89.4
685.8		18.5	26.2	32.8	35.8	41.7	44.7	53.6	60	62.6	68.5	74.5	77.5	83.1	92.3	101	107	116
762.0		23.2	32.8	41.7	47.7	50.7	56.6	65.6	74.5	80.5	86.4	95.4	98.3	98	116	125	137	146
914.4		35.8	47.7	59.6	68.5	77.5	83.4	98.3	110	119.2	128.1	137	146	155	170	188	203	215
1066.8		47.7	68.5	83.4	95.4	107.2	116.2	134.1	152	164	178.8	191	203	212	235	256	277	298
1238.4		65.6	89.4	110	128	143	155	179	203	221	238.4	253	268	280	316	349	373	399
1371.6		83.4	116.2	143	164	181.8	200	232	260	289	304	325	346	361	405	444	477	510
1524		101	143	175	203	226.5	247	286	319	352	375	400	423	447	498	542	587	626

Dia. In mm		CUBIC METERS PER SECOND																
		Pipe Pressure in kPa																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.050	0.056	0.071	0.085	0.100	0.113
304.2	Length = 122 m	2.38	3.27	4.17	4.8	5.4	6	6.9	7.5	8.3	8.9	9.5	10.1	10.7	11.9	13.1	14.3	15.2
381		4.17	5.66	7.15	8.05	9.24	10.1	11.6	12.8	14.3	15.5	16.4	17.6	18.5	20.6	22.6	24.4	26.2
457.2		6.26	8.94	11	12.8	14.3	15.5	17.9	20.3	22	23.8	25.6	26.8	28.6	32.8	35.7	38.7	41.7
533.4		8.94	12.8	15.8	18.2	20.3	22.1	25.6	28.6	32.8	35.8	35.8	38.7	42	44.7	50.7	536	56.6
609.6		12.5	17.6	21.5	25	28	29.8	35.8	38.7	44.7	47.7	51	53.6	57	62.6	68.5	74.5	80.5
685.8		16.4	23.2	28.6	32.8	35.8	41.7	47.7	51	56.6	62.6	66	68.6	74.5	83	89.4	98.3	104
762.0		20.9	29.2	35.8	41.7	47.7	50.7	60	66	71.5	77.5	83	89.4	92	104	113	125	131
914.4		29.8	44.7	53.6	62.6	71.5	77.5	89.4	98	107	116	125	134	140	158	173	185	197
1066.8		44.7	62.6	77.5	89.4	98.3	107	125	140	152	164	175	185	197	221	238	262	277
1238.4		59.6	83.4	104.3	119.2	134	146	167	188	206	220	238	250	265	295	25	352	378
1371.6		77.5	107.3	134.1	152	170	188	215	241	265	286	307	325	343	381	417	453	486
1524		95	134.1	164	191	215	232	268	298	328	358	381	405	426	477	522	566	602

Dia. In mm		CUBIC METERS PER SECOND																
		Pipe Pressure in kPa																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.050	0.056	0.071	0.085	0.100	0.113
304.2	Length = 197 m	2.09	2.98	3.6	4.17	4.77	5.07	5.96	6.56	7.15	7.75	8.12	8.64	9.24	10.4	11.3	12.2	13.11
381		3.58	5.07	6.3	7.15	8.05	8.94	10.1	11.3	12.5	13.4	14.3	15.2	16.1	17.9	19.7	21.2	22.6
457.2		5.66	8.05	9.8	11.3	12.5	13.7	15.8	17.6	19.4	20.9	22.3	23.8	25	27.7	29.8	32.8	35.8
533.4		8.05	11.6	14.3	16.4	18.2	19.7	22.9	25.9	28.3	29.8	32.8	35.8	35.8	41.7	44.7	47.7	50.7
609.6		11.3	16.1	19.7	22.6	25	27.4	32.8	35.8	38.7	41.7	44.7	47.7	50.7	56.6	65.6	65.6	71.5
685.8		14.9	21.1	25.9	29.8	33	35.8	41.7	47.7	50.7	56.6	59.6	62.6	65.6	74.5	80.5	86.4	92.4
762.0		19.1	26.8	32.8	38.7	42	47.7	53.6	59.6	66	68.5	74.5	80.5	83.4	95.4	104	110	119
914.4		28.9	41.7	50.7	56.6	65.6	71.5	80.5	92.4	98.3	107	113	122	128	143	155	167	179
1066.8		41.7	56.6	72	83.4	92.3	101	116	131	143	152	164	173	182	203	221	238	256
1238.4		56.6	80.5	95	113	125	137	158	176	191	206	221	232	244	274	298	322	346
1371.6		71.5	101	125	143	161	175	203	229	247	268	286	304	322	358	390	423	453
1524		92.3	128	158	182	203	221	256	289	313	337	358	381	402	447	495	530	566

Table F-4b
Capacity of Corrugated Metal Pipe Culverts
Without Headwalls and With Outlet Submerged (outlet control-full flow) (Circular) (Metric Units)

Dia. In m		m^3 PER SECOND																
		Head on Pipe in m																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.051	0.057	0.071	0.085	0.099	0.113
0.305	Length = 6.10 m	0.3	0.43	0.53	0.61	0.67	0.73	0.85	0.94	1.04	1.13	1.22	1.28	1.34	1.52	1.64	1.77	1.88
0.381		0.52	0.73	0.88	1.04	1.16	1.25	1.46	1.61	1.77	1.92	2.07	2.16	2.29	2.56	2.8	3.02	3.35
0.457		0.79	1.1	1.34	1.58	1.74	1.89	2.19	2.44	2.68	2.9	3.05	3.35	3.35	3.96	4.27	4.57	4.88
0.533		1.10	1.55	1.89	2.19	2.44	2.68	3.05	3.35	3.66	3.96	4.27	4.57	4.88	5.49	5.79	6.4	6.71
0.610		1.49	2.07	2.56	2.93	3.35	3.66	4.27	4.57	5.18	5.49	5.79	6.1	6.4	7.32	7.92	8.53	9.14
0.686		1.89	2.68	3.35	3.66	4.27	4.57	5.49	6.1	6.4	7.01	7.62	7.92	8.53	9.45	10.36	10.79	11.89
0.762		2.38	3.35	4.27	4.88	5.18	5.79	6.7	7.62	8.23	8.84	9.75	10.06	10.7	11.89	12.8	14.02	14.94
0.914		3.66	4.88	6.1	7.01	7.92	8.53	10.06	11.28	12.19	13.11	14.02	14.94	15.85	17.37	19.2	20.72	21.95
1.067		4.88	7.01	8.53	9.77	10.79	11.89	13.72	15.54	16.76	18.29	19.5	20.73	21.64	24.07	26.21	28.35	30.48
1.219		6.71	9.14	11.28	13.11	14.63	15.84	18.29	20.73	22.56	24.38	25.9	27.42	28.65	32.31	35.66	38.1	40.84
1.372		8.53	11.89	14.63	16.76	18.59	20.42	23.72	26.52	29.52	31.09	33.22	35.36	36.88	41.45	45.41	48.77	52.12
1.524		10.36	14.63	17.98	20.73	23.16	25.30	24.26	32.61	35.97	38.4	40.89	3.28	45.72	50.9	55.47	60.04	64.0

Dia. In m		m^3 PER SECOND																
		Head on Pipe in m																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.051	0.057	0.071	0.085	0.099	0.113
0.305	Length = 12.19 m	0.26	0.34	0.43	0.49	0.55	0.61	0.70	0.76	0.85	0.91	0.97	1.04	1.1	1.22	1.34	1.46	1.55
0.381		0.43	0.58	0.73	0.82	0.94	1.04	1.19	1.31	1.46	1.58	1.68	1.8	1.89	2.10	2.32	2.5	2.68
0.457		0.64	0.91	1.13	1.31	1.46	1.58	1.83	2.07	2.26	2.44	2.62	2.74	2.93	3.35	3.66	3.96	4.27
0.533		0.91	1.31	.61	1.86	2.07	2.26	2.62	2.93	3.35	3.66	3.66	3.96	4.27	4.57	5.18	5.49	5.79
0.610		1.28	1.8	2.19	2.56	2.86	3.05	3.66	3.96	4.57	4.88	5.18	5.49	5.79	6.4	7.01	7.62	8.23
0.686		1.68	2.38	2.93	3.35	3.66	4.27	4.88	5.18	5.79	6.4	6.71	7.01	7.62	8.53	9.14	10.1	10.67
0.762		2.13	2.99	3.66	4.27	4.88	5.18	6.1	6.71	7.32	7.92	8.53	9.14	9.45	10.7	11.58	12.8	13.41
0.914		3.05	4.57	5.49	6.4	7.32	7.92	9.14	10.1	10.79	11.89	12.8	13.72	14.32	16.15	17.68	18.9	20.11
1.067		4.57	6.4	7.92	9.14	10.1	10.97	12.8	14.32	15.54	16.76	17.98	18.9	20.11	22.56	24.36	26.82	28.35
1.219		6.1	8.53	10.69	12.19	13.72	14.94	17.07	18.20	14.69	22.56	24.38	25.6	27.13	30.17	33.22	36.0	38.71
1.372		7.92	10.87	13.72	15.54	17.37	19.20	21.95	24.69	27.13	29.26	31.39	33.22	35.06	39.01	42.67	46.32	49.7
1.524		9.75	13.72	16.76	19.51	21.95	23.77	27.43	30.48	33.53	36.58	39.01	41.45	43.59	48.77	53.34	57.91	61.6

Dia. In m		m^3 PER SECOND																
		Head on Pipe in m																
		0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034	0.040	0.045	0.051	0.057	0.071	0.085	0.099	0.113
0.305	Length = 18.29 m	0.21	0.3	0.36	0.43	0.49	0.52	0.61	0.67	0.73	0.79	0.85	0.88	0.94	1.07	1.16	1.25	1.34
0.381		0.37	0.52	0.64	0.73	0.82	0.91	1.04	1.16	1.28	1.37	1.46	1.55	1.64	1.83	2.0	2.16	2.32
0.457		0.58	0.82	1.0	1.16	1.28	1.4	1.61	1.8	1.98	2.13	2.29	2.44	2.56	2.83	3.05	3.35	3.66
0.533		0.82	1.19	1.46	1.68	1.86	2.01	2.35	2.65	2.9	3.05	3.35	3.66	3.66	4.27	4.57	4.88	5.18
0.610		1.16	1.65	2.01	2.32	2.56	2.8	3.35	3.66	3.96	4.27	4.57	4.88	5.18	5.79	6.4	6.71	7.32
0.686		1.52	2.16	2.66	3.05	3.35	3.66	4.27	4.88	5.18	5.74	6.1	6.4	6.7	7.62	8.23	8.84	9.45
0.762		1.95	2.74	3.35	3.96	4.26	4.88	5.49	6.1	6.71	7.01	7.62	8.23	8.53	9.75	10.67	11.28	12.14
0.914		2.96	4.27	5.18	5.79	6.7	7.32	8.23	9.45	10.1	10.70	11.58	12.5	13.11	14.63	15.85	17.07	18.29
1.067		4.26	5.79	7.32	8.53	9.45	10.36	11.89	13.41	14.6	15.54	16.76	17.68	18.59	20.73	22.56	24.38	26.21
1.219		5.79	8.23	9.75	11.58	12.8	14.02	16.15	17.98	19.51	14.63	22.56	23.77	25.0	28.04	30.48	32.92	35.36
1.372		7.32	10.36	12.8	14.63	16.45	17.98	20.73	23.47	25.3	27.43	29.26	31.09	32.92	36.58	39.93	43.28	46.33
1.524		9.44	13.11	16.15	18.59	20.73	22.56	26.21	29.57	32.0	34.44	36.58	39.01	41.15	45.72	50.6	54.25	57.91

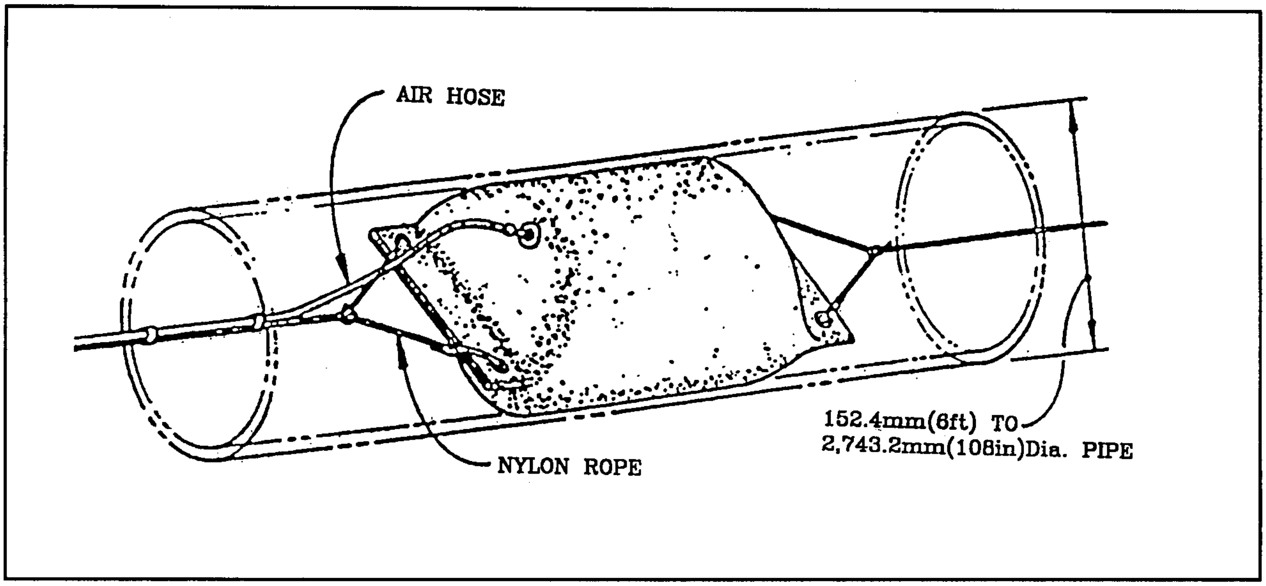

Figure F-5. Prefabricated rubber pipe stoppers for outlet opening of a manhole

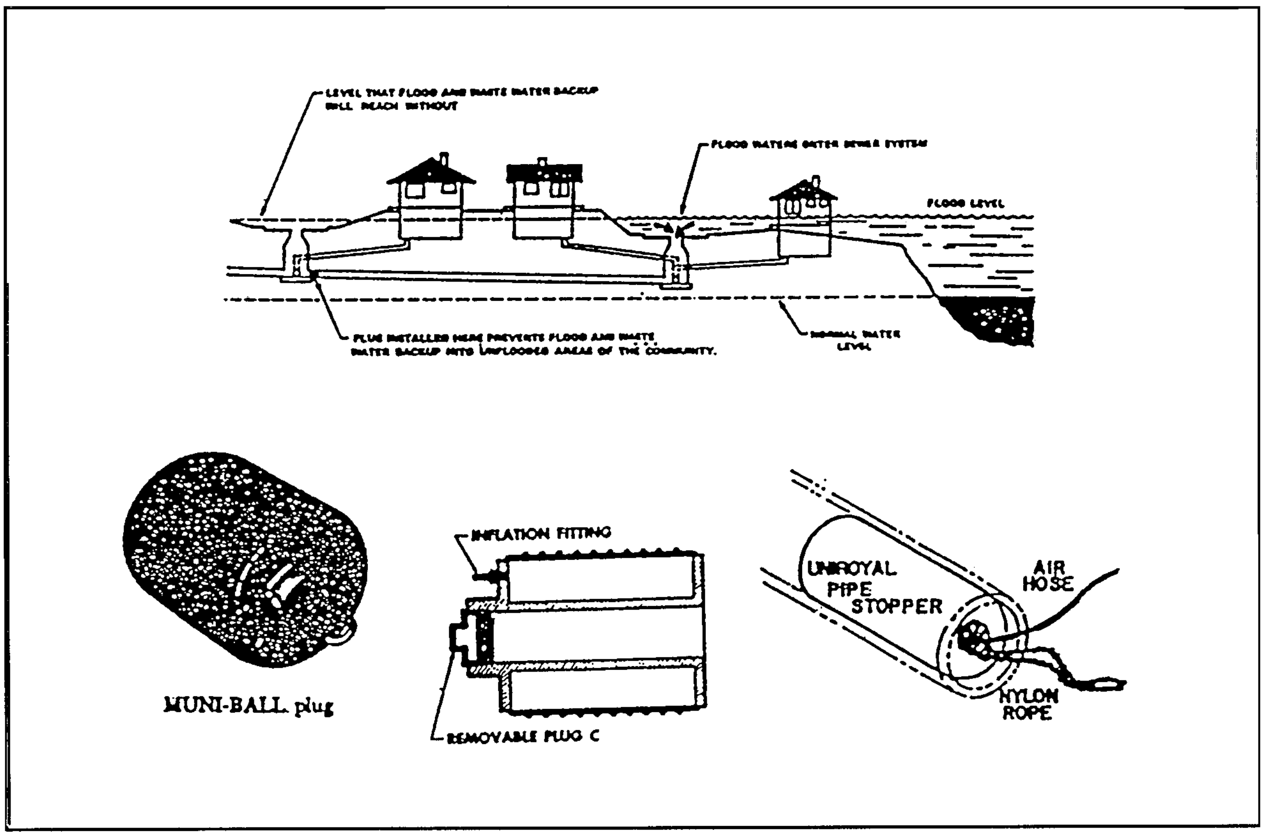

Figure F-6. Prefabricated rubber pipe stoppers for outlet opening of a manhole

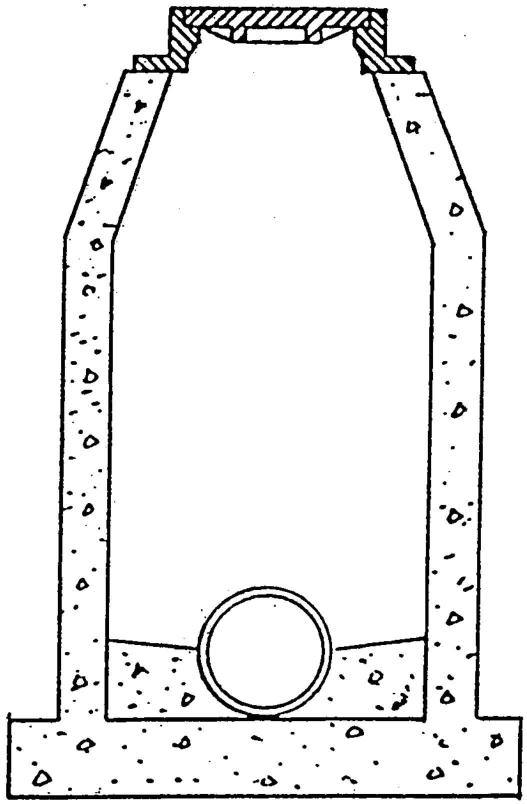

Figure F-7. Typical manhole

construction equipment. However, if the flood barrier consists of poly and sandbags having a minimum top width and limited base width, raising the barrier is very time consuming and labor intensive. Experience has shown that sandbag barriers over 0.91 m (3 ft) in height do not perform well for prolonged floods; underseepage becomes a real problem and failures have occurred as the water approaches the top of protection.

c. Seepage. Seepage is percolation of water through or under a levee, generally appearing first at the landside toe. Seepage through the levee is applicable only to a relatively pervious section. Seepage, as such, is generally not a problem unless (1) the landward levee slope becomes saturated over a large area; (2) seepage water is carrying material from the levee; or (3) pumping capacity is exceeded. Seepage which causes severe sand boils and piping is covered below. Seepage is difficult to eliminate, and attempts to do so may create a much more severe condition. Pumping of seepage should be held to a minimum, based on the maximum ponding elevation without damages. Seepage should be permitted if no apparent ill-effects are observed, and if adequate pumping capacity is available. If seepage causes sloughing of the landward slope, it should be flattened to 1V on 4H or flatter. Material for flattening should be at least as pervious as the embankment material.

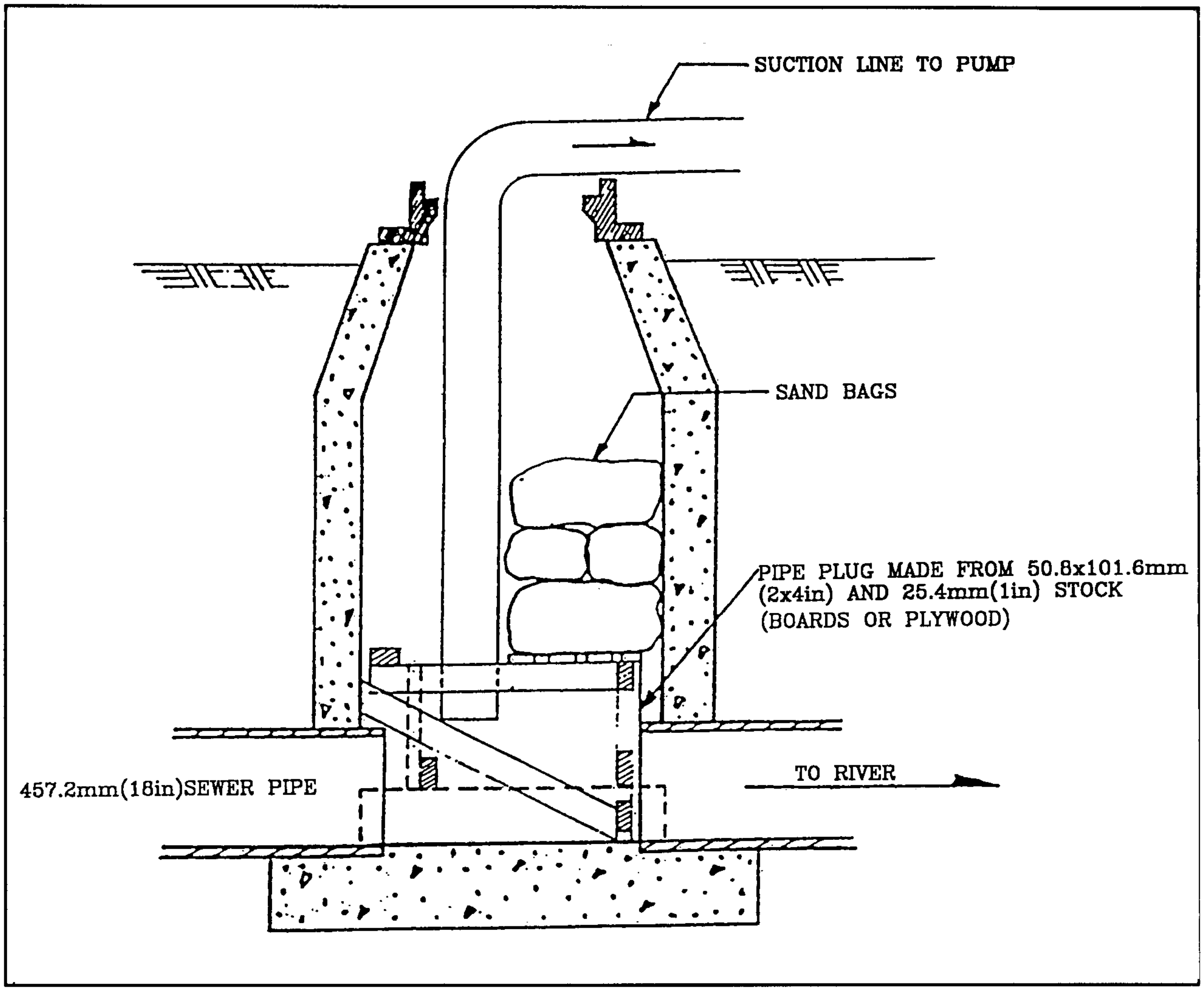

Figure F-8. Adapting manhole for use as emergency pumping station

d. Sand boils.

(1) Description. A sand boil is the rupture of the top foundation stratum landward of a levee caused by excess hydrostatic head in the substratum. Even when a levee is properly constructed and of such mass to resist the destructive action of floodwater, water may seep through a sand or gravel stratum under the levee and break through the ground surface on the landside in the form of bubbling springs. When such eruptions occur, a stream of water bursts through the ground surface, carrying with it a volume of sand or silt which is distributed around the hole. A sand boil may eventually discharge relatively clear water, or the discharge may contain quantities of sand and silt, depending upon the magnitude of pressure and the size of the boil. They usually occur within 3.05 m to 91.4 m (10 to 300 ft) from the landside toe of the levee, and in some instances have occurred up to 304.8 m (1,000 ft) away.

(2) Destructive action. Sand boils can produce three distinctly different effects on a levee, depending upon the condition of flow under the levee.

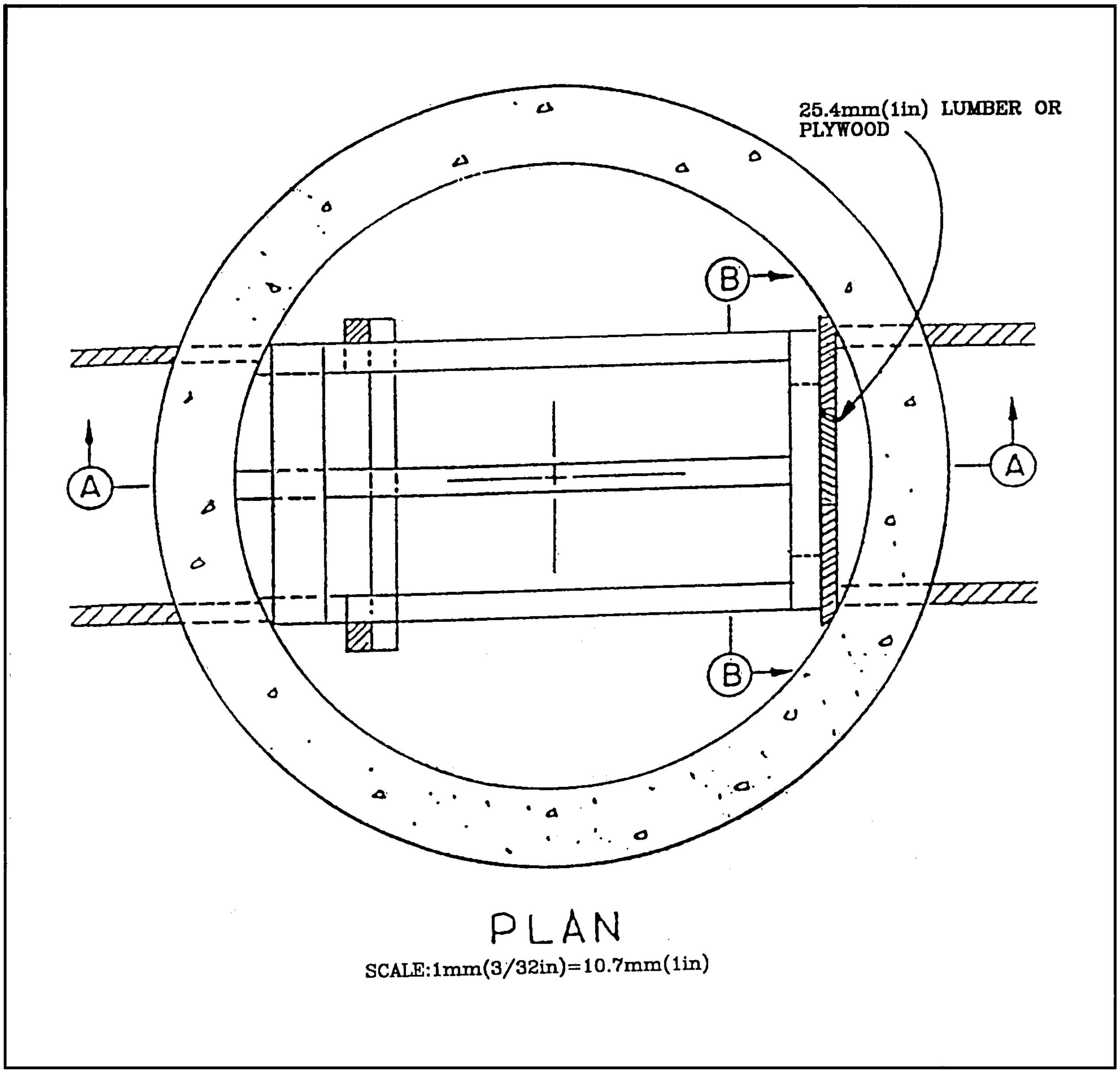

Figure F-9. Sealing top of manhole with wood

(a) Piping flow. Piping is the active erosion of subsurface material as a result of substratum pressure and concentration of seepage in the localized channels. The flow breaks out at the landside toe in the form of one or more large sand boils. Unless checked, this flow causes the development of a cavern under the levee, resulting in the subsidence of the levee and possible overtopping. This case can be easily recognized by the slumping of the levee crown.

(b) Non-piping flow. In this case, the water flows under pressure beneath the levee without following a defined path, as in the case above. This flow results in one or more boils outcropping at or near the landside toe. The flow from these boils tends to undercut and ravel the landside toe, resulting in sloughing

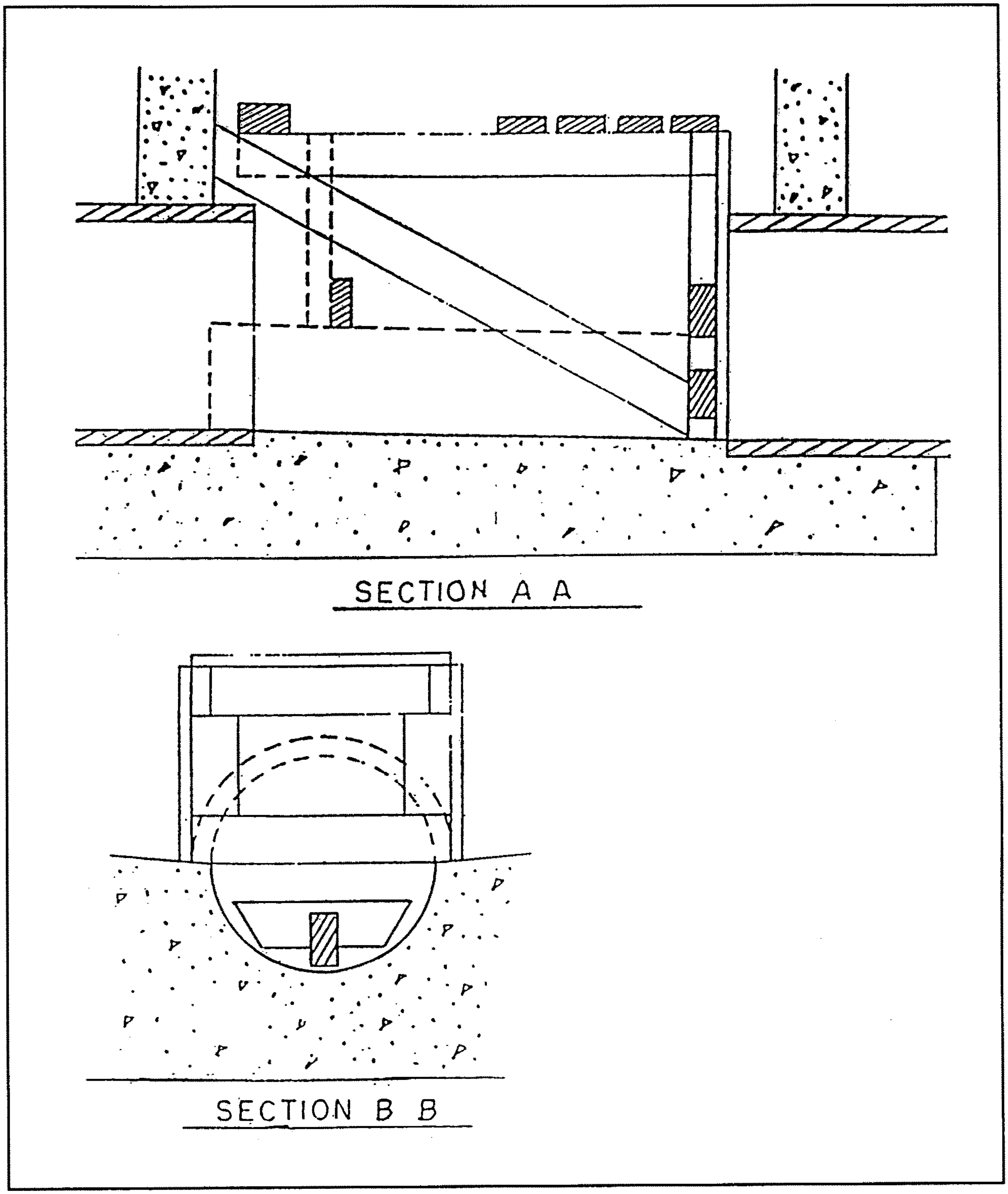

Figure F-10. Treatment of bottom of manhole

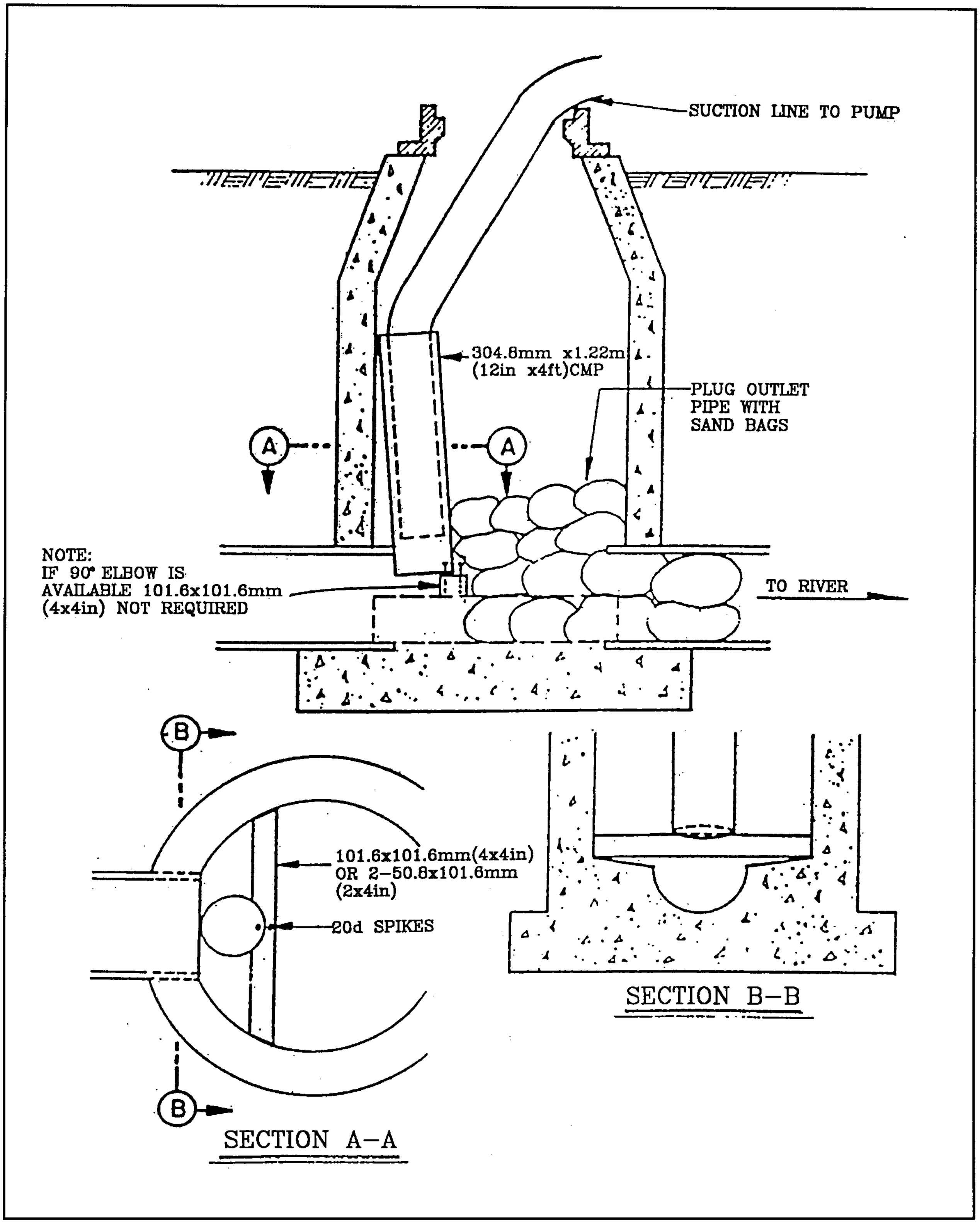

Figure F-11. Suction line to pump from manhole

of the landward slope. Evidence of this type of failure is found in undercutting and ravelling at the landside toe.

(c) Saturating flow. In this case, numerous small boils, many of which are scarcely noticeable, outcrop at or near the landside toe. While no boil may appear to be dangerous in itself, the consequence of the group of boils may cause flotation ("quickness") of the soil, thereby reducing the shearing strength of the material at the toe, where maximum shearing stress occurs, to such an extent that failure of the slope through sliding may result.

(3) Combating sand boils. All sand boils should be watched closely, especially those within 30.5 m (100 ft) of the toe of the levee. All boils should be conspicuously marked with flagging so that patrols can locate them without difficulty and observe changes in their condition. A sand boil which discharges clear water in a steady flow is usually not dangerous to the safety of the levee. However, if the flow of water increases and the sand boil begins to discharge material, corrective action should be undertaken immediately. The accepted method of treating sand boils is to construct a ring of sandbags around the boil, building up a head of water within the ring sufficient to check the velocity of flow, thereby preventing further movement of sand and silt. See Figure F-12 for technique in ringing a boil. Actual conditions at each sand boil will determine the exact dimensions of the ring. The diameter and height of the ring depend on the size of the boil and the flow of water from it. In general, the following considerations should control: (1) the base width of the sandbag section should be no less than 1 1/2 times the contemplated height; (2) encompass weak soils near the boil within the ring of sandbags, thereby preventing a potential failure later; and (3) the ring should be of sufficient size to permit sacking operations to keep ahead of the flow of water. The height of the ring should only be that necessary to stop movement of soil, and not as high as to completely eliminate seepage. The practice of carrying the ring to the river elevation is not necessary and may be dangerous in high stages. If seepage flow is completely stopped, a new boil will likely develop beyond the ring; this boil could then suddenly erupt and cause considerable damage. Where many boils are found to exist in a given area, a ring levee of sandbags should be constructed around the entire area and, if necessary, water should be pumped into the area to provide sufficient weight to counterbalance the upward pressure.

e. Erosion. Erosion of the riverside slope is one of the most severe problems which will be encountered during a flood fight. Emergency operations to control erosion have been presented earlier under "Slope Protection."

f. Storm and sanitary sewers.

(1) Problems. Existing sewers in the protected area may cause problems because of seepage into the lines, leakage through blocked outlets to the river, manhole pumps not spread throughout the sewer system, and old or abandoned sewer locations which were not found during preflood preparations. Any of these conditions can cause high pressures in parts of the sewer system and lead to the collapse of lines at weak points and blowing off of manhole covers.

(2) Solutions. During the flood fight, continued surveillance of possible sewer problems is necessary. If the water level in a manhole approaches the top, additional pumps in manholes may alleviate the problem. In sanitary sewers, additional pumping may be required at various locations in the system to provide continued service to the homes in the protected area. When pumps are not available, manholes may have to be ringed with sandbags or by some other method which allows the water to head up above the top of the manhole. To eliminate the problem of disposing of this leakage from manholes the ring dike would have to be raised above the river water surface elevation. This creates high pressures on the sewer and should not be done. As with sand boils, it is best to ring the manhole part way to reduce the head and dispose of what leakage occurs. Directly weighing down manhole covers with sandbags or other-items is not recommended

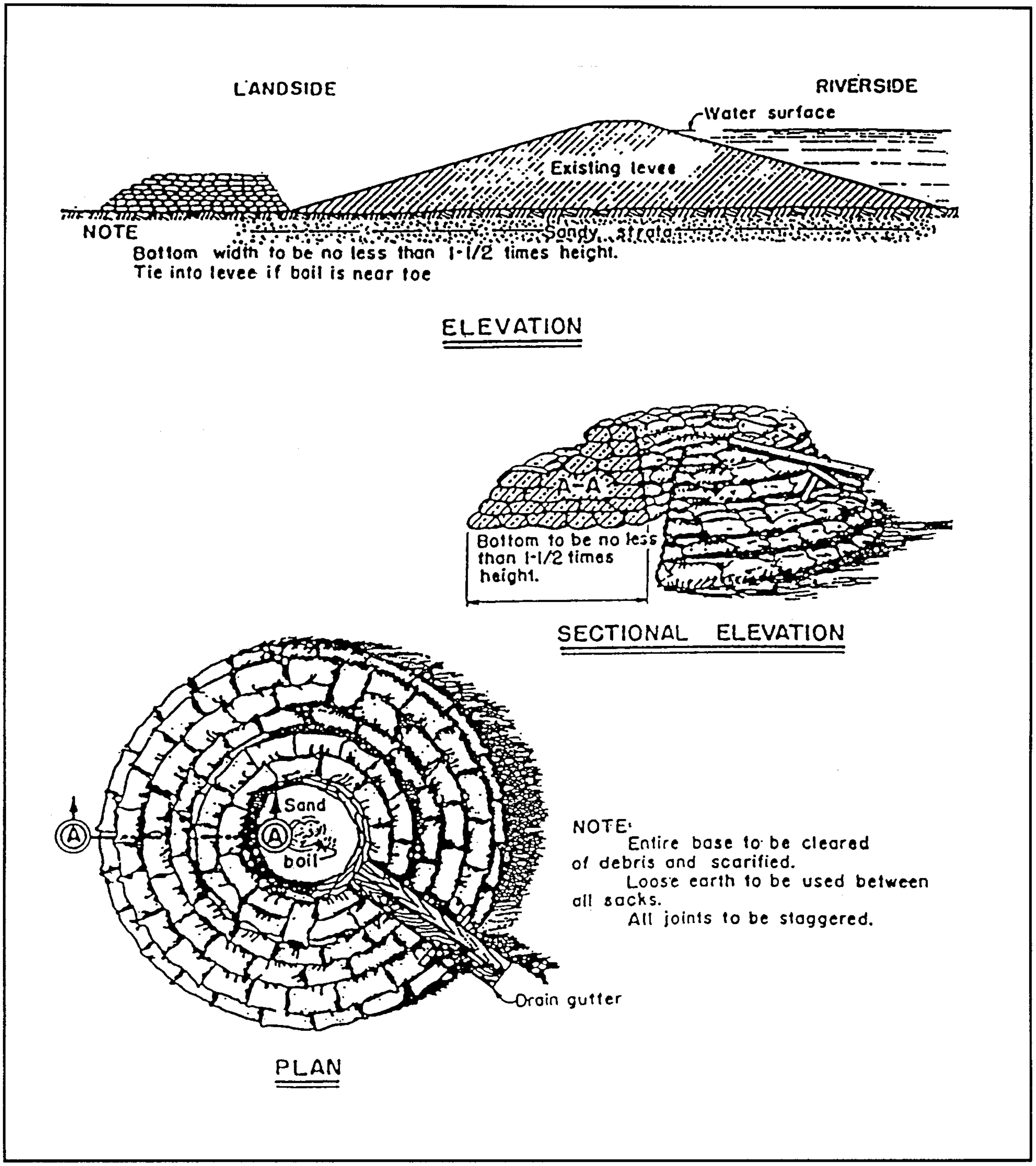

Figure F-12. Ringing sand boils

where high heads are possible. A 30-kPa (10-ft) head on a manhole cover 0.61 m (2 ft) in diameter would exert a force of 9.16 kN (2,060 lb-force). Thus, a counterweight of more than a ton would have to be placed directly on the cover.

g. Slope stability on weak foundations. In areas that have very weak foundation soils it may not be possible to construct full height flood barriers in preferred locations because of inadequate slope stability. However, if flood waters are slow to rise and fall, it is possible to use the rising floodwater as a restraining load on the riverside slope to meet stability criteria. This is usually used for closure structures or for staged construction where the flood barrier is only constructed after the river reaches an established level. This procedure would also require that the flood barrier be removed before the river went down below the established level.

h. Causes of levee failures. In addition to the problems covered above, the following conditions could contribute to failure:

(1) Joining of a levee to a solid wall, such as concrete or piling. Flood barriers consisting of sandbags greater than 0.91 m (3 ft) in height and joining a solid wall have performed poorly in the past due to excessive underseepage and instability of the sandbag prism.

(2) Structures projecting from the riverside of levee.

(3) A utility line crossing or a drain pipe through the fill.

(4) Tops of stoplogs on roads or railroad tracks at a lower elevation than the levee.

(5) Joining a sandbag barrier to a levee. Seepage problems at the juncture with the levee fill have caused very poor performance.